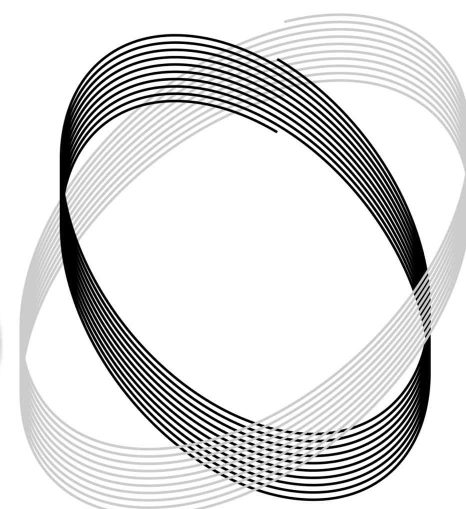

Design of a double aperture Canted-cosine-theta orbit corrector for the High Luminosity LHC

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ABSTRACT

The High Luminosity LHC requires dipole orbit correctors grouped in double aperture magnet assemblies. They provide a field of 3.1 T at 100 A in an aperture of 70 mm.

A new design is needed based on a radiation-resistant polyimide insulated cable that can replace the existing orbit correctors when they reach their end-of-life due to radiation damage. The challenge is to design a magnet that simply plugs into the existing positions and re-uses bus-bars, passive quench protection, and power supplies.

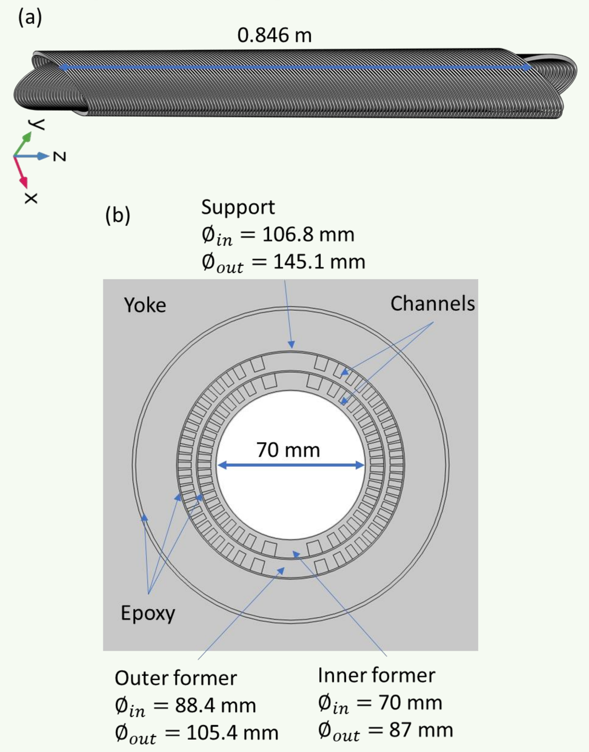
We propose, through a collaboration with Swedish universities and Swedish industries, to design a self-protected canted-cosine-theta (CCT) design. We take the opportunity to explore new concepts for the CCT design to produce a cost-effective and high-quality design with a more sustainable use of resources. The new orbit corrector's design must fit with tight field quality requirements while keeping within the same mechanical volume and maximum excitation current.

MAIN PARAMETERS

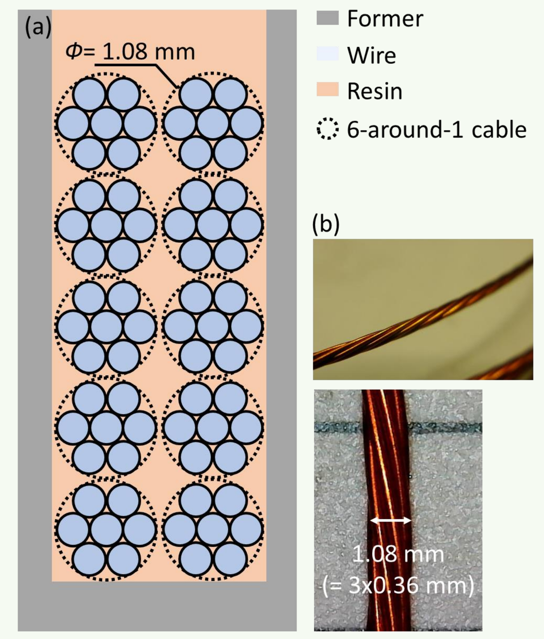
Main parameters based on the LHC MCBC [1,2]

Parameters	Values
Overall length	1.1 m
Nominal current (per wire)	85 A
SC cable	6-around-1
SC cable diameter	1.08 mm
SC wire	NbTi 0.36 mm
Critical current (at 4.2 K)	137 A
Pitch	5.8 mm
Nb turns	147
Tilt angle	30°
Thickness of the formers	2.35 mm
Wall thickness (min)	0.3 mm
Channels design	2 x 5 cables
Channel dimensions	2.31 x 6.15 mm^2

3D view (a) and 2D view (b) of the CCT magnet showing main parameters



View of the wires in the channel (a) and photography of the cable (b)

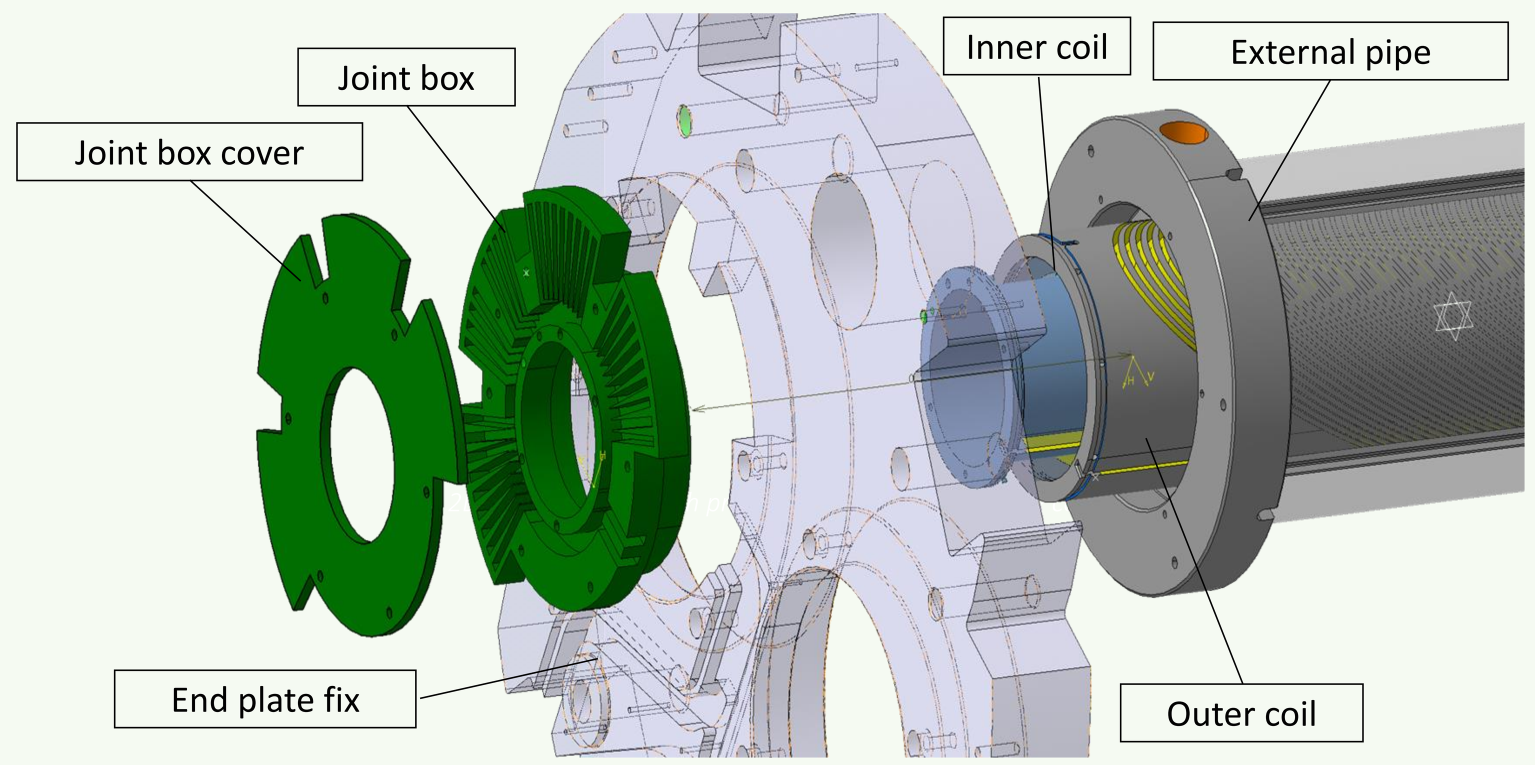


CAD MODEL AND TESTS

CAD design is ongoing, and involves major improvements compared to existing CCT magnets [4]. The improvements are on three different areas: layer jump, joints boxes, quench protection.

A multi-layer jump box will be designed and installed on the side of the magnet. It will consist of three layers of G10, two are used for the 70 splices (35 splices per layer) and the last one for the instrumentation and voltage taps.

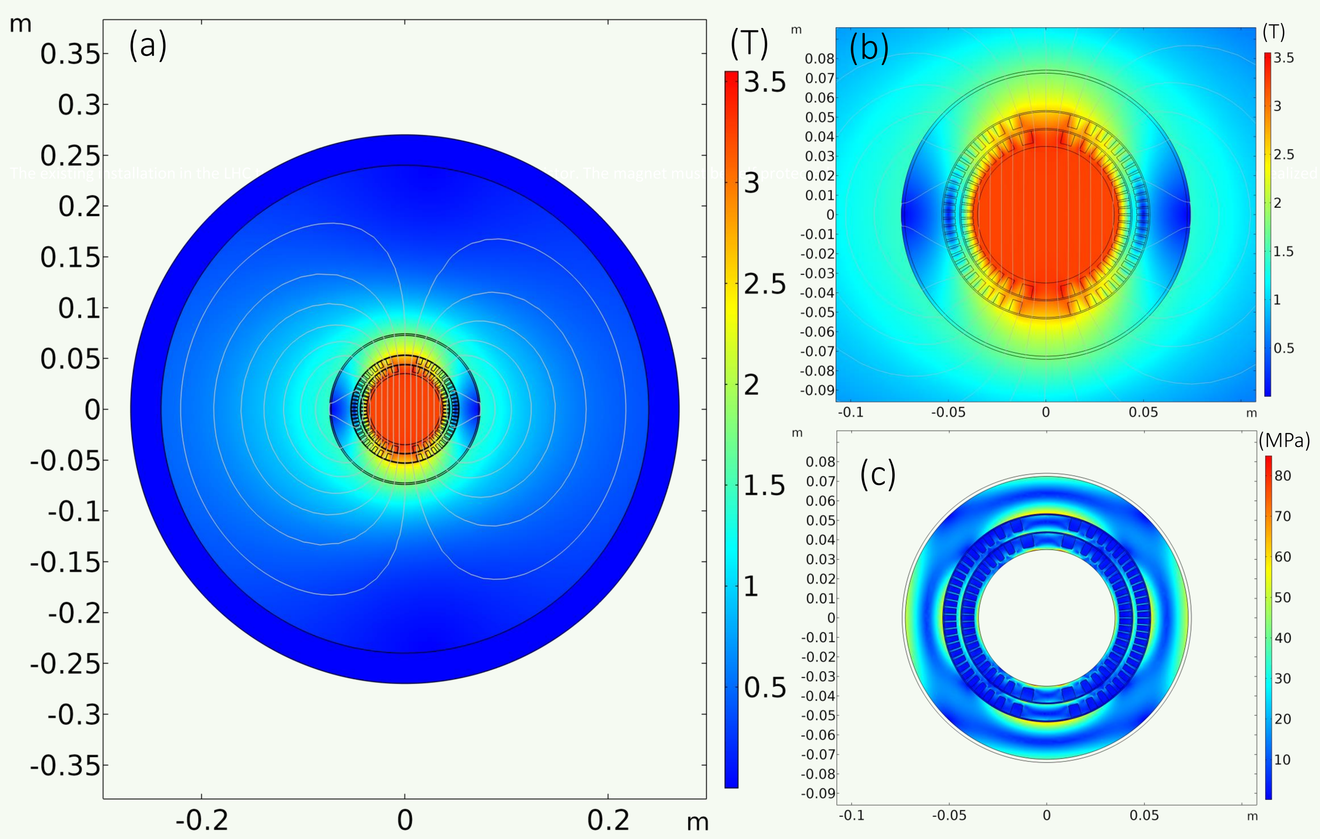
3D view of the coils with the joints box



SIMULATIONS

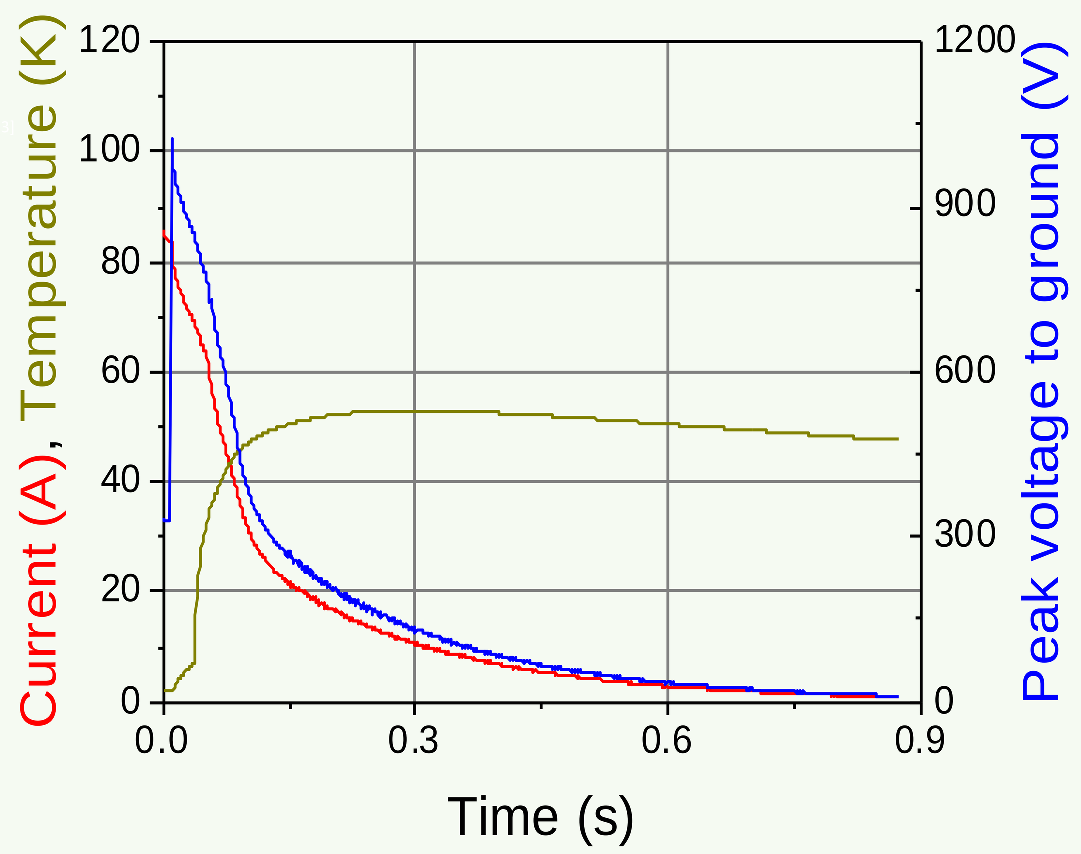
For a total current of 85 A per wire, a 6-around-1 cable and 10 cables in each channel, a peak field of 3.27 T is obtained. Considering the magnet length is 0.857 m for an overall length smaller than 1.1 m, we obtain an integrated field of approximately 2.80 Tm.

2D view of the magnetic field simulated by COMSOL with iron (a), zoom around the coil (b) and mechanical stress (c)



The existing installation in the LHC tunnel doesn't involve external dump resistor. The magnet must be self and passively protected. Simulations have been realized using ProteCCT [3] to estimate the needed the dump resistor.

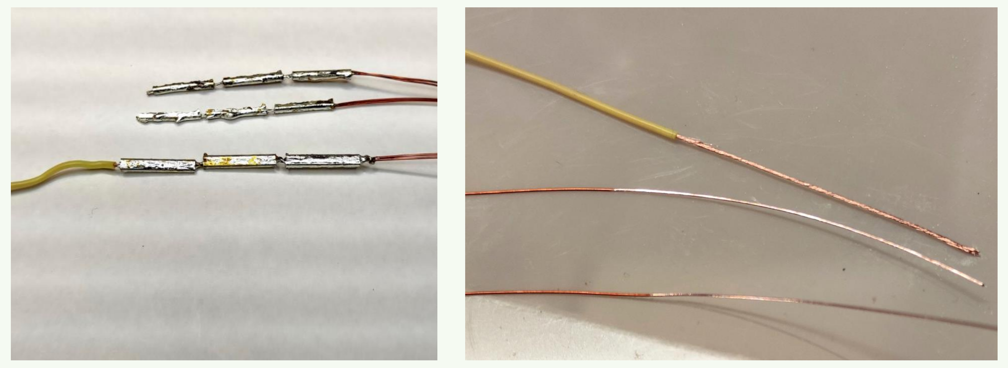
Quench protection studies with ProteCCT for I = 85 A and a dump resistor of 12.3 Ω



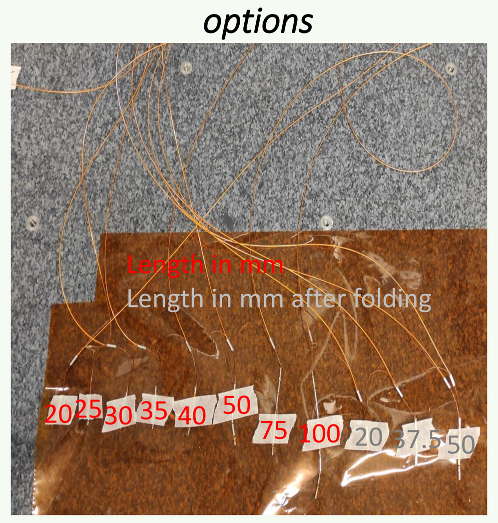
Realization of the 70 joints:

- The insulation is removed from the super conducting wire and voltage tap.
- The two superconducting (SC) wires are twisted together.
- The voltage tap is then twisted around the SC pair.
- Flux is added and all three wires are soldered together.
- Crimp tubes are put over the joint section.
- Flux is added again, and the solder is re-flown with additional solder added which flows into the crimp tubes.
- The joint is covered in a polyimide tube for insulation.

Photographs of the splices



Photographs of different splices options



View of 11 splices to be tested and compared to find the option offering the lowest resistance.

The splices are between 20 mm and 100 mm long.

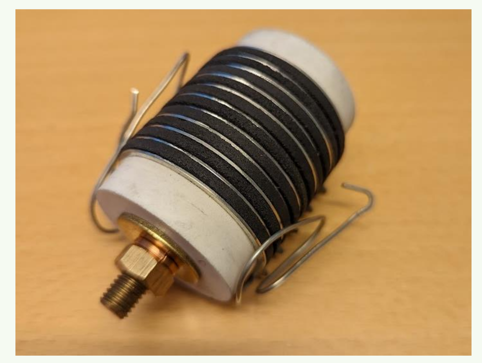
The three on the right are folded in half.

Rather than following the Ohm's law, a varistor exhibit the following VI relationship [5]:

$$V(T) = C(T)I^{\beta(T)}$$

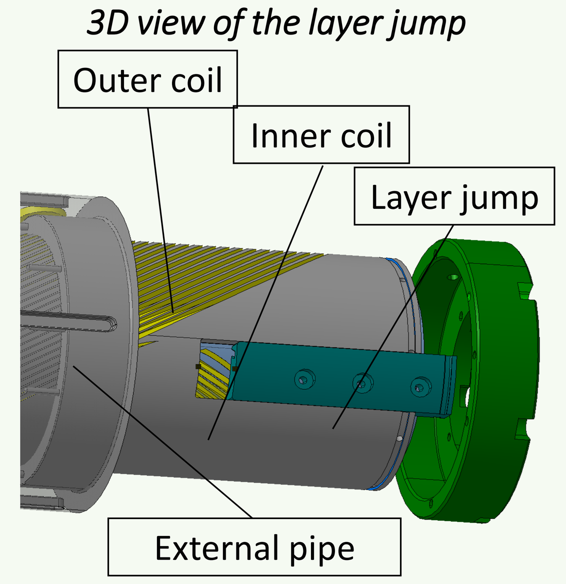
C is a scaling constant equal to the voltage across the varistor at 1 A and β is a non- linearity coefficient (<1).

Pictures of a Metrosil varistors



The layer jump will require several iterations to find the best model that is both efficient and easy to install.

3D view of the layer jump



CONCLUSIONS

The CCT magnet being designed and manufactured by two Swedish universities and Swedish industries is now fully simulated. The model will be ready for manufacturing in the next few weeks and will be tested at FREIA at Uppsala University. This magnet is based on the LHC MCBY and MCBC specifications and has three major improvements over other CCT magnets: improved layer jump, easily accessible jointed boxes and self protected.

[1] O. Brüning, et al. *LHC design report*
[2] A. Louzguiti, et al. *Design of Radiation Hard Spare Units for the Orbit Corrector Dipoles*
[3] M. Mentik, et al. *Quench behavior of the HL-LHC Twin Aperture Orbit Correctors*
[4] G. Kirby, et al. *Hi-Lumi LHC Twin-Aperture Orbit Correctors Magnet System Optimization*
[5] T. Galvin , et al. *Superconducting Magnet Energy Extraction with a Varistor to Reduce Quench Voltages and Hot spots*